Space Weather Technical Forecast

Issued on Sunday, 17 September 2023 at 01:26 Local

This technical forecast provides a four day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: A large centre-disc eruption observed early on 16th Sept produced an Earth-directed CME, expected to arrive on Tuesday 19th September, with likely G1-G2 minor/moderate storm. Chance of G1 early UTC day of Sunday. Chance of further G1 on Monday. Chance R1 throughout.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity was Moderate in the past 24 hours, with two M-class flares observed from AR3429 near centre-disc, with peaks of M2.9 at 16/0050 UTC and a M3.3 at 16/0538 UTC. There are currently seven sunspots regions on the disc, with AR3429 the most active, although there are now signs of an arriving region in the far east in the form of a new bi-polar group, as AR3423 becomes less distinct in the far west. The majority of the activity has occurred from AR3429 (Dac/Beta-Gamma-Delta), which contains a delta spot in its intermediate portion. This was very mobile in the period with its constituent parts well-formed and essentially orbiting each other at close quarters. Other spots on the disc were largely unremarkable, although the new eastern arrival did produce a C5.0 to perhaps hint at a degree of potential here.

A large-filament which has dominated the central-north disc in H-Alpha, was seen to finally lift-off the disc early on the 16th Sept, perhaps destabilised by the suite of M-class flares from nearby AR3429, situated to the south of the filament. This produced a halo CME, which has been analysed using LASCO-C3 coronagraph imagery, with the bulk of the material seen to be heading towards the south and west. Early results from this analysis suggest an arrival at Earth during the UTC day of 19 September (Day 3). However, further analysis is currently on-going of this event, so these details may change.

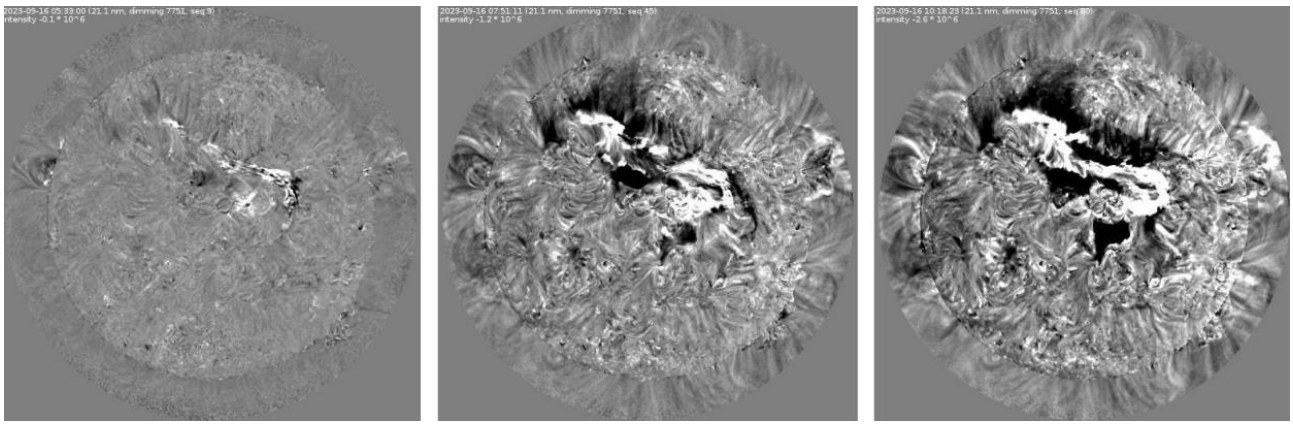

Figure 1: SIDC AIA211 time-integrated dimming of the large centre-disc fliament eruption which occurred early on 16 September and produced a halo CME, which has been analysted has arriving at Earth on 19 September – although further analysis is on-going at present.

The only other CME visible in coronagraphs in the period was a high-latitude feature apparently heading northeast. There is no obvious front-sided source and this is perhaps far-sided. No other

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CMEs were observed in the past 24 hours.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by DSCOVR (as well as ACE and STEREO A) near L1, are perhaps now thought most likely to be explained as the fast wind from CH47/-, with a possible onset having occurred on Thursday 14 September, but masked by an unusual preceding CIR. This is not a conclusive diagnosis, and there is a small chance of a fast wind arriving within the current UTC day, however this now appears unlikely. The solar wind speed showed a steady decline within a solidly negative phi sector (towards the Sun), with the speed falling from around 490 to 400km/s, closer to a slow regime. The solar wind density was level within its typical background scope of single figures ppcc, while the IMF was weak and below 6nT. The north-south component was variable but within a typical range of +/-5nT. The net result of the above solar wind measures was for provisionally Quiet to Unsettled geomagnetic activity, with a peak of Unsettled Kp 3 in the 18-21UTC interval.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux was at Background levels. GOES16 high energy (greater than 2MeV) electron flux was at Normal Background to Moderate levels. The associated 24-hour fluence was well below the Active threshold, with 6.52e6 integrated pfu observed at 17/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a daily Chance of M-class flares, mainly from AR3429 near centre-disc. The large but fading AR3423 should leave the Earth-facing side over the current UTC weekend, but the flare risk may be maintained by the return of Ex-AR3413 in the east.

Solar Wind / Geomagnetic Activity: The geomagnetic forecast is of lower than average confidence, for a full discussion please see the Geomagnetic Storms section.

The large filament eruption which occurred early on the UTC day of 16 Sept, produced a halo CME, which has been provisionally analysed and latest modelling suggests an arrival at Earth during the UTC day of 19 September (Day 3). However, please note, further analysis is on-going to firm up on the detail for this event. Therefore, the main forecast elements are the 14/0745UTC CME (especially), and to a lesser extent the 14/2126UTC CME.

Quiet-Unsettled initial conditions will Likely evolve to G1/Minor geomagnetic storm within the next 24 hours, receding into the new working week to be replaced by a further Chance of G1 during Monday morning UTC. The filament eruption, which produced the halo CME (mentioned above) is Likely to arrive on 19 September (Day 3) with G1-G2/Minor-Moderate Storm Likely and a Slight Chance of G3/Strong Storm, which may last into the early UTC of 20 September (Day 4).

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a daily Slight Chance of an enhancement should any larger flares occur.

High energy (greater than 2 MeV) electron flux is likely to be suppressed at Normal Background levels at GEO through much of the period, but perhaps with an eventual increase in the wake of CH47/-, now rendered lower confidence by intervening CMEs. Overall, the 24-hour fluence is Expected to remain below the Active threshold throughout the period, with reducing confidence into the new UTC week.

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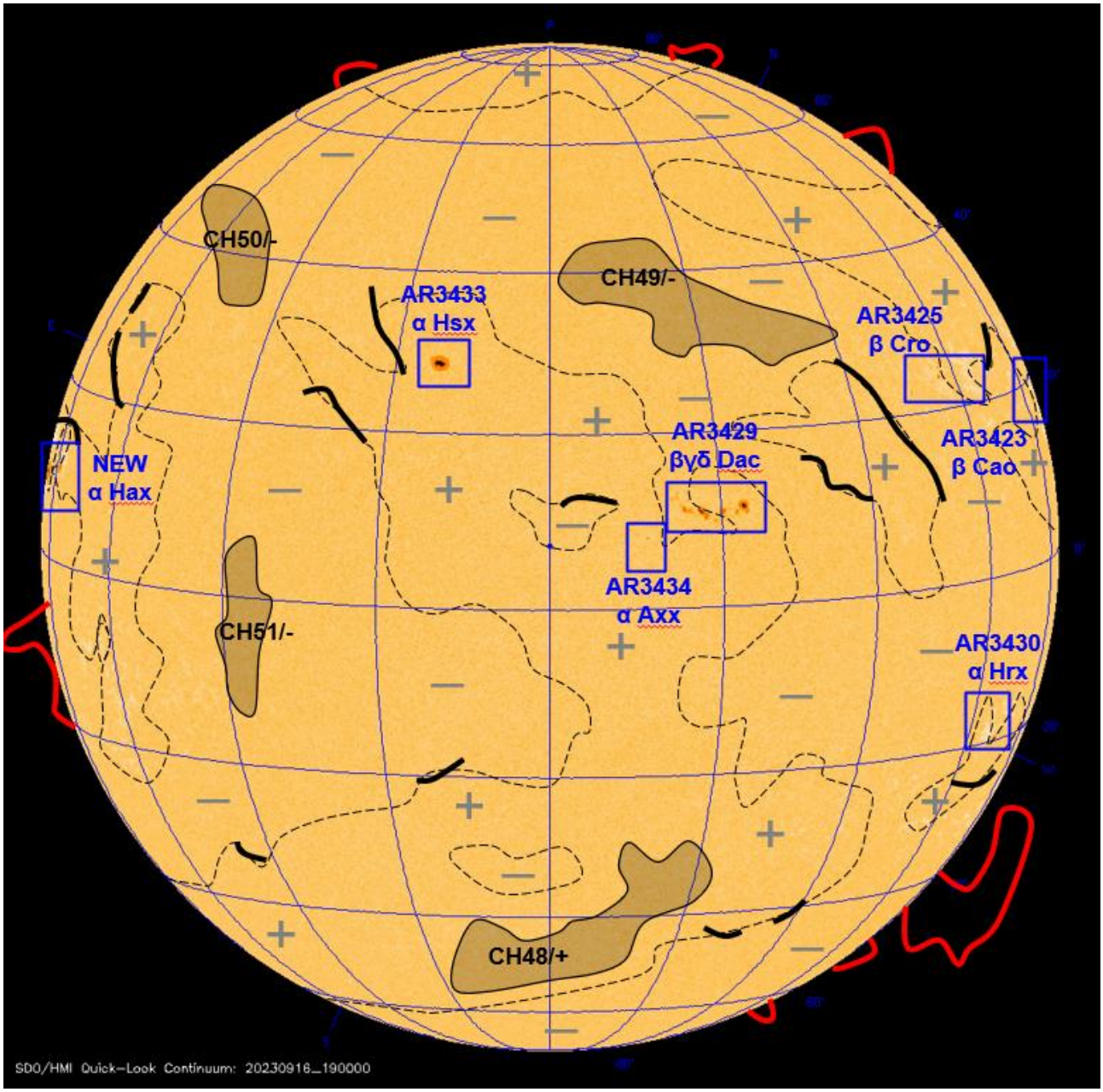
Figure 2. Solar Analysis Valid 16/1900 UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

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Geomagnetic Storms:

Thinking surrounding current geomagnetic conditions has changed is the past 24 hours. Limited positive phi angle has been observed recently, and CH44/+'s fast wind is likely to have passed above Earth. This may have contributed slightly to the CIR seen from Thursday 14 September at L1, however this CIR is now considered to perhaps have been the fore-runner into CH47/-. CH47 has therefore perhaps been in progress since - given Slightly Elevated solar winds and a steady (mostly) negative phi angle. The recently observed solar wind is therefore below persistence and expectations for this feature, which had been thought likely to approach 600km/s. This difference does now mean that MOSWOC Enlil's forecast is perhaps nearer the expected evolution of the solar wind, and confidence in its treatment of CME arrival times is increased.

There are currently three CMEs that feature in the forecast.

The first and main CME in the forecast was from a large filament eruption in the northwest, associated with an M1.4 flare near AR3423 around 14/0745UTC. This feature was mainly directed north and west of the Sun-Earth line, however a partial halo shock (at least) was observed. The modelled arrival time of this CME was adjusted forwards, to account for what were then seen as Enlil model deficiencies (in the lack of a 600km/s fast wind from CH47/-), however modelling is now considered to be more reflective of current conditions than expected, and an arrival time in the UTC early hours of Sunday 17 September.

The second CME was likely associated with an M2.4 flare from AR3229 at 14/2126UTC. Although the flare was narrowly in the northeastern quadrant, the CME appears to be directed slightly south and east, with consensus opinion suggesting possible arrival in the UTC morning of Monday 18 September.

The third and probably the most significant CME in the forecast is from the large filament eruption, which occurred early in the UTC day of 16 September. The large filament has been dominant in the central-north disc in H-Alpha and was finally seen lifting off the disc early on 16 September, perhaps destabilised by a series of M-class flares from the nearby AR3429, situated to the south of the filament. This produced a asymmetric halo CME seen clearly in LASCO-C2 and C3 coronagraph imagery, also STEREO-A, with the bulk of the material heading to the south and west. The CME has been provisionally analysed and modelled in Enlil, which suggests a likely arrival time at Earth during the UTC day of Tuesday 19th September. However, please note, further analysis is on-going to firm up on the detail for this event.

Geomagnetic activity forecast is lower than average confidence. The main forecast elements are the 14/0745UTC CME (especially), and to a lesser extent the 14/2126UTC CME, with the significant CME arriving on the 19 September from the filament eruption on the 16 September.

Initially Quiet conditions should give way to a Chance of G1-G2 early in the UTC day of Sunday 17 September. From here, a further Chance of G1 from the 14/2126UTC CME follows on Monday 18 September. Further G1-G2/Minor-Moderate storm likely, with Slight Chance of G3/strong storm during the UTC day of 19 September, due to the arrival of the halo CME from the filament eruption on 16 Sept, with the effects perhaps lingering into the early UTC day of 20 September, before waning.

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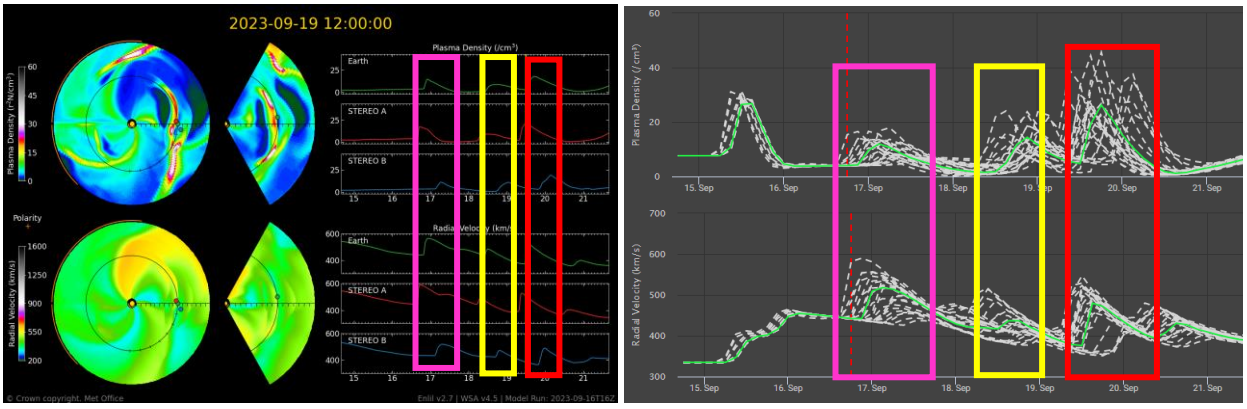
Geo-Magnetic Storm Probability (Exceedance)	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Minor or Moderate	G1 to G2	No	20	30	70	50
Strong	G3	No	1	5	20	10
Severe	G4	No	1	1	1	1
Extreme	G5	No	1	1	1	1

Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
14/1159	Partial	Filament eruption	NW near AR3432	830km/s	UTC evening 16 Sep	Reasonble chance of hit
15/0600	Partial	AR3429	M2.4 flare centre-disc	500km/s	18/0900UTC	Edge hit. Low confidence
16/0800-1000UTC	Full	Filament eruption	Centre-disc	Range from 600-1100km/s – further analysis	19/1200 UTC	Reasonable hit, but requires further analysis.

Figure 2: MOSWOC Enlil and ensemble shows the potential 3 CMEs currently in the forecast, with the 1st (pink box) likely to arrive early on the current UTC day, with 2nd (yellow box) arriving early on the 18 September. The 3rd (red box) is associated with the filament eruption and halo CME, likely to arrive on 19 September.



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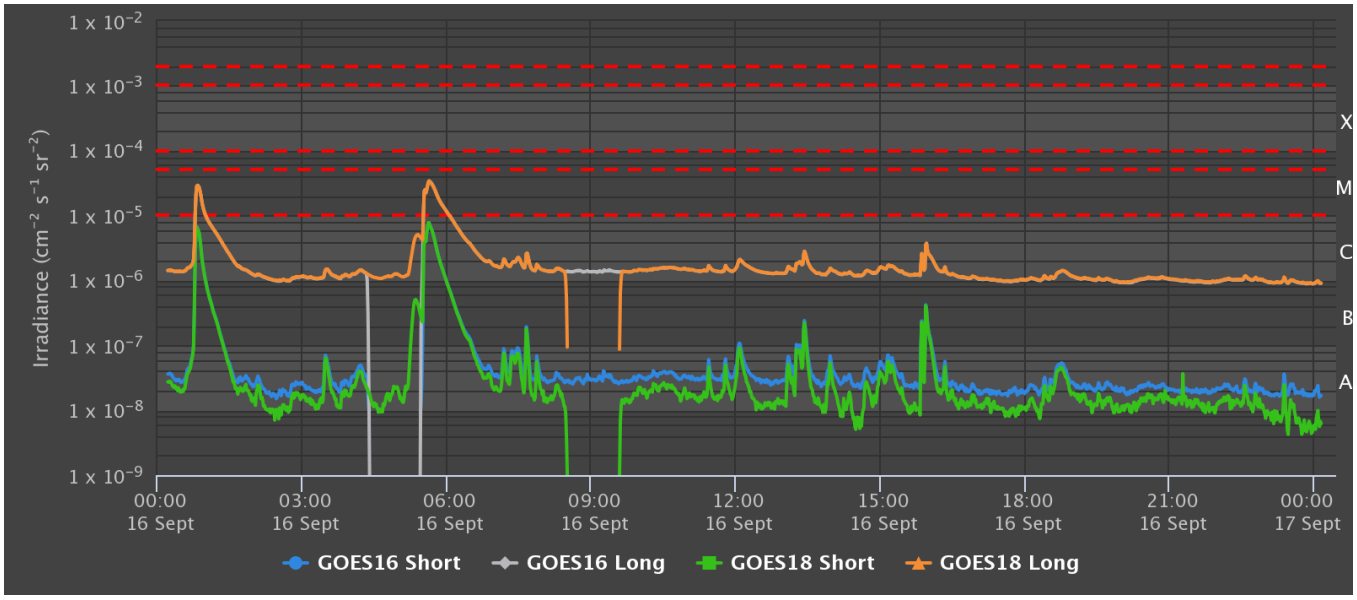
Radio Blackouts - X-Ray Flares:
Current X-ray activity is heavily tied to the fortunes of the Mt Wilson delta spot contained within centre-disc AR3429. The constituent parts of this delta are currently very mobile and appear to be in orbit of each other in the past 24 hours. The evolution from here is uncertain - they could now separate or else continue their interaction, however given the current state of affairs the X-ray risks are felt to have to rise above raw values. The rationale for this being that the raw values only account for Zurich classes, and the activity is more likely down to features not captured by this system (i.e. mobility, growth and the delta itself).

In terms of the forecast, AR3423 is expected to rotate off the visible disc over the UTC weekend, however a large region is expected to rotate over the eastern horizon to mitigate against any otherwise declining risk. This arriving region is expected to be the returning Ex-AR3413, which was responsible for numerous M-class flares during when last on the visible disc. This group may now be emerging on the far eastern solar horizon, however as yet its leading spot is the only part visible, and the current UTC morning's C5.0 is perhaps an underestimate of its capability.

X Ray Flares	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC)	Day 2 (00-24 UTC)	Day 3 (00-24 UTC)	Day 4 (00-24 UTC)
Probability			(%)	(%)	(%)	(%)
Active	R1-R2 M Class	Yes	50	50	50	50
Very Active	R3 to R5 X Class	No	10	10	10	10

Figure 3: GOES X-Ray flares



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Solar Radiation Storms - (High Energy Protons):
The high energy (greater than 10MeV) proton flux observed by GOES16 is expected to persist at Background levels. There remains a daily Slight Chance of flux levels rising in response to any significant flaring, with the risk raised a little relative to raw values as these are based on Zurich classes and most activity is felt to be due to the Mt Wilson delta in AR3429 at present. The focus is now also gradually moving from AR3423 (currently near the western limb) to central AR3429.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ S1**	No	10	10	10	10
Very Active	**≥ S3 ***	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

High Energy Electrons Event (≥ 2MeV):
High energy (greater than 2MeV) electron flux levels are currently at Normal Background levels. Thoughts are now changing as to the likely state of upcoming fast wind streams, perhaps most specifically that CH44/+ has very likely missed, and CH47/- may already be in course - this despite the slightly unusual observation that the solar wind speed decreased slightly in the wake of the CIR.

This unfortunately lowers confidence in forecast electron populations at GEO still further, although the net result is perhaps inconsequential as Active fluence is probably less likely. The rationale for this is that there is now a significant departure from the Strong fast wind from CH47's predecessor, with 450-500km/s instead observed, and even this is now waning. While a degree of recovery is now expected in electron populations, perhaps within the current UTC day, the expected arrival of CMEs in the coming days should repeatedly impede recovery and perhaps redistribute any limited gains from CH47 - if it is already present.

The overall forecast is therefore a Slight Chance on all days, rising slightly as the risk of CMEs fades.

GEO Electron Environment Probability (Exceedance)	Level (cm^{-2} sr^{-1} day^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	1	10
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

Figure 4: MOSWOC REFM electron fluence, observations and recurrence.

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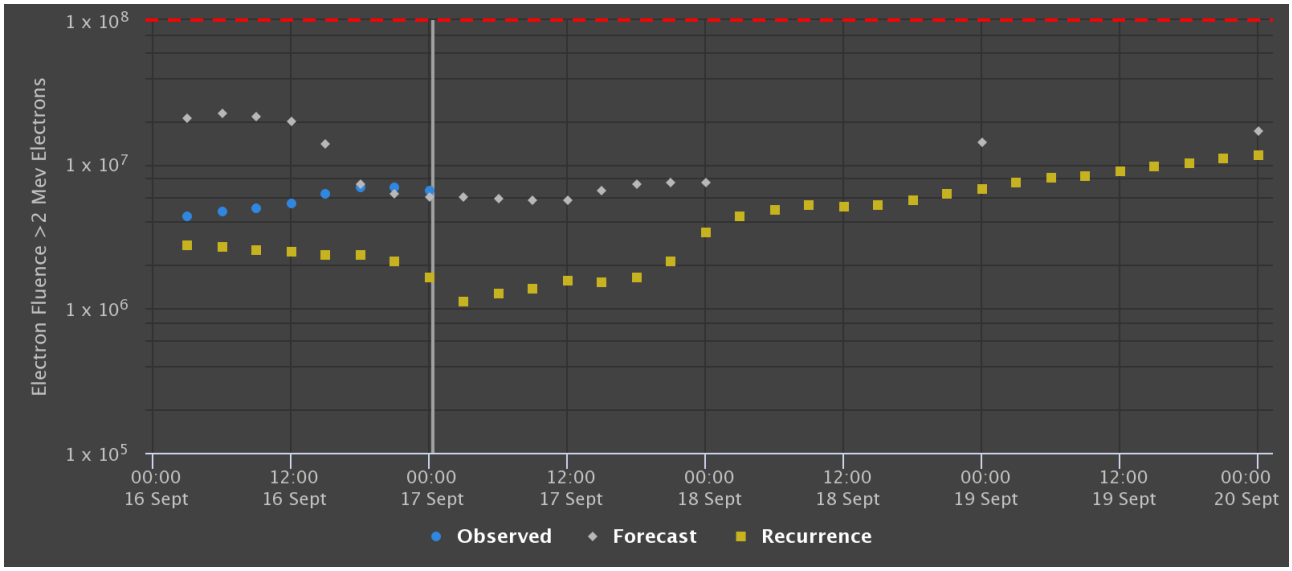

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